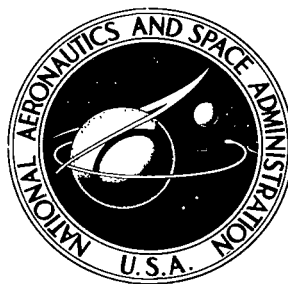


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ACOUSTIC DATA FROM THE LAUNCH OF SCOUT S-172C (ESRO I-B) AND SCOUT S-169 (GRS-A)

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16. Abstract <p>Acoustic data were obtained during the launch of the ESRO I-B spacecraft on October 1, 1969, and the GRS-A spacecraft on November 7, 1969, by Scout launch vehicles. The internal noise environment was monitored by a microphone located immediately below the spacecraft separation plane on S-172C. During both launches external noise levels were measured by microphones located on the launcher.</p> <p>The highest internal sound pressure was observed at liftoff at an overall level of 133 dB over a 10- to 2000-Hz bandwidth. The highest overall external sound pressure was 149 dB, observed during liftoff.</p> <p>The Scout heat shield exhibits good noise-attenuation characteristics (15 to 25 dB) from 40 to 1000 Hz and readily transmits subaudio frequencies (10 to 20 Hz) as well as frequencies above 1000 Hz. The ring frequency of this heat shield is calculated to be 1236 Hz.</p> <p>In addition to the microphones, transducers were included in the S-172C flight experiment to measure the following performance parameters: steady and low-frequency accelerations, spin rate, motor pressure, tip-off, coning, chuffing, ambient pressure, and spacecraft separation.</p>					
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ACOUSTIC DATA FROM THE LAUNCH OF SCOUT S-172C (ESRO I-B) AND SCOUT S-169 (GRS-A)

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INTRODUCTION

Scout-launched spacecraft experience noise caused by the reflected sound field of engine exhaust during liftoff and by boundary layer noise from aerodynamic sources acting on the space vehicle's outer skin during transonic flight. Random vibration laboratory tests simulate the in-flight noise environment and are adequate for small spacecraft that offer very short transmission paths for mechanically induced vibrations. However, larger spacecraft provide filtering of vibrations applied at the bottom, and the upper regions are inadequately tested. Acoustic testing gives assurance, through air-path coupling, that panels and structure are being adequately tested for the random noise environment.

With this in mind, Goddard Space Flight Center has been concentrating on acoustic testing of spacecraft. Concurrently, GSFC has been working on programs to obtain in-flight acoustic data. The S-172C flight offered the first opportunity to obtain in-flight acoustic data inside the heat shield of a Scout vehicle. In addition, three microphones were mounted on the vehicle launcher in the vicinity of the payload. These launcher microphones also recorded the external noise at liftoff of the Scout S-169 used to launch the GRS-A. This report is a summary of the acoustic data obtained from these launches.

In addition to the microphones, transducers were included in the S-172C flight experiment to measure the following performance parameters: steady and low-frequency accelerations, spin rate, motor pressure, tip-off, coning, chuffing, ambient pressure, and spacecraft separation.

The "E" section S-172C performance experiment was implemented by the Langley Research Center as a secondary experiment. The primary payload was the European Space Research Organization satellite, ESRO I-B. The Scout vehicle (S-172C) was launched by the Air Force Space Systems Command from Space Launch Complex 5 (SLC-5), Air Force Western Test Range (WTR), California, on October 1, 1969. The

ESRO I-B was placed in an elliptical earth orbit. The Scout vehicle (S-169) launched the German Research Satellite (GRS-A/AZUR) into an earth orbit on November 7, 1969, from the same launch pad. The S-169 did not include a flight-performance experiment.

DESCRIPTION OF THE VEHICLE AND PAD CONFIGURATION

Scout S-172C was a standard Scout B four-stage solid-propellant booster system developed by the Langley Research Center. The Scout vehicle on its launch pad is shown in Figure 1. Figure 2 shows the general arrangement of the vehicle.

The first-stage rocket motor was an Aerojet General ALGOL II-B, serial number 63. This motor developed a maximum thrust of 482,684 newtons at T+0.16 seconds. The nozzle exit area was 0.5267 meters.

During ascent, the payload was protected by the Scout 0.86-meter heat shield. This slightly bulbous, clamshell-type shield was a glass fiber and honeycomb composite split shell structure 0.015-meter thick with a 0.0013-meter thick outer layer of cork. The heat shield was ejected just prior to third-stage ignition when the vehicle was out of the sensible atmosphere. The ejection was accomplished by the use of latch-contained springs, after the prior release of latches and clamps effected by a ballistic actuator and drawbar. The Scout S-169 employed a similar technique.

The Scout Mark II launcher-tower is provided with a movable base to permit azimuth control between 65 and 205 degrees and with a cantilevered elevating launch boom to permit pitch control to the 90-degree position required for launch. With the launcher in a vertical position, the first-stage nozzle is 4.34 meters above the concrete pad.

The launcher-tower, as shown in Figure 3,* is located on a dry concrete pad bounded on the east and north by a hill, as shown in Figure 1. First-stage exhaust is free to disperse in all directions with the exception of the launcher-tower direction, where an inverted conical deflector protects parts of the launcher mechanism. The exhaust impinges on a flat concrete pad protected by an ablative material. Pad dimensions (concrete area) are 36.58 meters by 39.62 meters. Its elevation is 99.06 meters above sea level.

INSTRUMENTATION

The primary objective of the "E" section performance experiment was to measure the performance of the fourth-stage rocket motor, United Technology Center's FW-4S. Goddard Space Flight Center was responsible for performing the measurements of in-flight noise level in the payload area, as well as for providing the launcher with microphones to determine the noise level external to the shroud. This was the first Scout launch vehicle to be instrumented for measurements of pressure and noise level within the payload shroud. The performance sensors provided information on acceleration, low-frequency vibrations, spin rate, tip-off, coning, motor pressure, and chuffing. Figure 4 shows the general location of the microphones; Figure 5 is a detailed photograph

*The launcher base is located at the north end of the pictured shelter within the circle seen on the pad.

Table 1—S-172C "E" section telemetry channel assignments.*

Function	Range	Channel
Ambient pressure	0 to 103,421 newton/meter ²	9
Horizon scanner		10
Fourth-stage motor pressure	0 to 6,205,284 newton/meter ²	11
Longitudinal acceleration	-1 to +30 g	12
Transverse acceleration	±0.5 g	13
Normal acceleration	±0.5 g	15
Longitudinal acceleration	±0.5 g	16
Airborne noise	150 dB	17
Separation sensor		18

*After Black, C. E., and Latimer, J. L. III, "Scout S-172C Final Flight Report", LTV Aerospace Corp., Dallas, 1969.

of the installation on the "E" section. Table 1 lists the instrument range and telemetry channel assignments.

Signals from the transducers were conditioned and fed into an FM/FM telemeter. The RF signal was then recorded and stored on an onboard magnetic tape loop recorder with a 45-second loop. The data were transmitted (delayed 45 seconds) to NASA and Western Test Range stations.

Of the three launcher microphones, two were mounted on the "D" arms (the upper set of circular "grabbers" in Figure 6) and one on the payload umbilical boom. The "D" arm microphones were 1.91 meters aft of the flight microphone when the vehicle was on the launcher. These microphones, mounted so that their receptors were facing aft (toward the ground), are shown in Figure 7. At liftoff, all the arms and booms were open. Figure 6 shows the open arms. The signals from the microphones were fed into amplifiers mounted on the launcher and through cable into the Scout blockhouse where they were recorded on magnetic tape by GSFC personnel. The frequency response for this system is shown in Figure 8a. Analysis showed good agreement between signals from the "D" arm microphones but a lower level from the umbilical microphone. It is not fully understood why the umbilical microphone data were lower in level, but in keeping with a conservative approach and the fact that the "D" arm microphones were in such good agreement, the lower level data were disregarded.

DATA REDUCTION

The flight data were obtained from a magnetic tape supplied by the NASA telemetry station. Data reduction consisted of producing the following derived records:

- (1) Oscillograph records for use in determining the nature of the data.
- (2) Detailed spectrum analysis describing the frequency composition and relative amplitudes of the background noise level.
- (3) Overall, 1-octave-, and 1/3-octave-band rms level records defining the acoustic environment.
- (4) Low-pass filtered oscillograph records and low-pass spectrographs for detailed study of the low-frequency data.

The users of the data, particularly those who are not intimately connected with the data-gathering and analysis process, must be informed of the validity and effectiveness of the reduced data. The following points are presented in this direction.

- (1) The 1-octave-band and 1/3-octave-band plots have been fully corrected for measurement-system frequency response, background noise level, and analysis-system frequency response. Frequency response curves are given in Figure 8.
- (2) The flight microphone system received an end-to-end system calibration (with and without flight tape recorder) of frequency response and amplitude linearity prior to launch. The launcher microphones were end-to-end calibrated before and after launch. No changes were noted. The calibrations recorded on magnetic tape were used to adjust the analysis equipment. All calibrations were carried out with microphone calibrators and with electrical calibration-insert signals.
- (3) The in-flight tape recorder introduced a high background noise level in the data. Spectrum analysis revealed the noise to peak at 1330 Hz. A 1/3-octave-band analysis of the background noise level is shown in Figure 9. This accounts for the lack of a 1000-Hz data point in the octave band plots. To establish the increasing slope to 2000 Hz and the high level at the 2000-Hz octave band (Figure 10b), a 1/3-octave-band analysis was carried out. To the author's knowledge, this is the first acoustic data from a launch vehicle which exhibit an increasing level in the high-frequency region.
- (4) Since the "E" section data were transmitted with a 45-second delay, the loss of signal at T+33 and T+42 in Figure 11a occurred in real time at T+78 and T+87; these two times correspond to second-stage ignition and second-stage loss of signal, as illustrated in Figure 26 of Reference 1. It is unfortunate that loss of signal occurred just when acoustic noise should have been increasing in the region of maximum dynamic pressure.

FLIGHT TIME HISTORY

As a reference for the data, time histories of Mach number, dynamic pressure, and ambient pressure are given in Figure 12. Figure 13 presents altitude and velocity profiles, and Figure 14 presents a detailed altitude plot for the first 1.9 seconds.

At launch time for S-172C, the weather was foggy and hazy with a 60.96-meter overcast. The temperature was 290K, the dewpoint was 288K, and the relative humidity was 84 percent. The wind was from 330 degrees at 3.1 meters/second. Barometric pressure was 99,617 newtons/meter².

For the launch of S-169, the weather was clear with a high, thin overcast and scattered clouds at 243.84 meters and 4572 meters. The temperature was 286K, the dewpoint was 284K, and the relative humidity was 83 percent. The wind was from 170 degrees at 4.1 meters/second. Barometric pressure was 99,921 newtons/meter².

DISCUSSION AND RESULTS

Rocket-engine exhaust and aerodynamic disturbances are the principal sources of the high-intensity noise environment for launch vehicles. During the liftoff phase, the rocket-engine exhaust is the major source. Maximum internal acoustic noise levels were registered during this time period (T+0 to T+2 seconds). The internal acoustic spectrum during liftoff is affected by properties of the rocket booster, such as thrust output, nozzle diameter, and number of engines; launch pad structural configuration; topography of the local terrain; noise-reduction properties of the shroud; acoustic properties of the interior volume; and atmospheric conditions.

After liftoff, the maximum in-flight internal acoustic noise level occurred during transonic flight and was lower than that measured at liftoff. The in-flight noise levels are generated by shock-wave and separated-flow effects over the vehicle body. These in turn depend on the shroud configuration, vehicle angle of attack, atmospheric conditions, noise-reduction properties of the shroud, and acoustic properties of the interior volume.

Figure 11a shows the overall sound-pressure level (OA SPL) time history for the flight microphone, which measured 133 dB at liftoff and 130 dB at transonic. Figure 11b shows a time-expanded OA SPL time history for the flight microphone. It can be seen that the maximum level was reached at T+0.73 seconds when the vehicle was 7.01 meters off the pad.

The OA SPL for the launcher microphone peaked at ignition at 149 dB and is shown in Figure 15. External levels again started to increase at T + 1.75 seconds. The vehicle's exhaust was approaching the microphones, and the data are clipped at T + 2.2 seconds, when band-edge levels are exceeded. Launcher microphone data after T + 1.5 seconds are not considered usable for comparison with internal shroud data in the evaluation of shroud attenuation. The launcher microphone was located 23.16 meters above the pad, and at T + 1.75, the vehicle was 21.15 meters above the pad.

Figure 10a shows the maximum octave-band (OB) SPL curve of the launcher microphones for the first 1.5 seconds of the S-172C launch. The maximum levels in the octave bands occurred at different times during this 1.5-second period; therefore, the computed OA SPL of 149 to 150 dB is higher than the maximum level of 149 dB shown in Figure 15. Launcher microphone data for the S-169 launch is shown in Figure 16b. The

higher computed OA SPL of 150 to 151 dB is attributed to the tolerances of the sound measuring system. An rms level time history for the S-169 is shown also in Figure 15.

The flight data for S-172C are shown in Figure 10a. These plots also represent the maximum points in each OB and show data for liftoff and transonic. Due to a high background noise level introduced by the in-flight tape recorder, data could not be recovered in the 1000-Hz OB. The detailed spectral analysis of the background noise level (Figure 9) revealed that a 1/3-OB analysis could be accomplished and would provide more curve points in the high-frequency region with a loss of the 1250-Hz 1/3-OB only. The resultant 1/3-OB analysis is shown as Figure 10b, and the reader is cautioned to note that the 1250-Hz data points are missing. It is unfortunate that the electrical noise frequency peaked near the calculated heat shield ring frequency of 1236 Hz. The wide difference in the low-frequency region (12.5 Hz) between the liftoff and transonic spectrum shown in Figure 10b was evident in the oscillograph record of the composite signal. Figure 17 shows this low-frequency signal at liftoff. Figure 17a is a spectrograph of frequency versus time for the flight microphone, with the relative noise level indicated by the shading between grey and black (black indicates the higher level). There is a significant low-frequency tone at ignition that shifts to higher frequency with time. This effect was not recorded by the launcher microphone. Figure 17b shows a 50-Hz low-pass oscillograph record of the same data.

Next, the data were analyzed to determine the noise attenuation characteristics of the heat shield (Figure 18). Readings at nine discrete times for each 1/3-OB during the first 1.5 seconds of launch were averaged for the external and internal microphones. The reader is cautioned to note that the 1250-Hz 1/3-OB data point was interpolated from the slopes of the curves on either side. Subtracting the internal curve from the external curve results in the attenuation curve. The heat shield shows attenuation characteristics of 15 to 25 dB from 40 to 1000 Hz, with less attenuation in the subaudio region and near the shroud's calculated ring frequency.

CONCLUSIONS

The highest overall sound-pressure level inside the heat shield was 133 dB, recorded at 0.73 seconds after ignition. The Scout vehicle was 7.01 meters off the pad at this time.

The highest overall sound-pressure level outside the heat shield was 149 dB, recorded at ignition. The microphone recording this sound pressure was located on the Scout launcher.

The external launcher-mounted microphones from two different Scout launches recorded signals in substantial agreement.

The heat shield readily transmits sound at subaudio frequencies below 20 Hz, and an interpolation of the data curve indicates that sound is readily transmitted at 1236 Hz also, which is coincident with the shroud's calculated ring frequency.

The heat shield provides sound attenuation of 15 to 25 dB between 50 and 1000 Hz.

RECOMMENDATIONS

The in-flight loop tape recorder produced high background noise levels and obscured important high-frequency data associated with the ring frequency of the heat shield. The in-flight recorder also caused a loss of high-frequency data during the maximum dynamic-pressure period of flight. High-frequency acoustic noise produces damage to thin-film experiment windows, barriers, foils, gratings, and concentric slits; hence, this loss is highly undesirable.

It is recommended that additional Scout vehicles be instrumented to obtain acoustic data within the heat shield. It would be most desirable to transmit real-time data on IRIG* channel E or on a higher channel.

ACKNOWLEDGMENTS

The author wishes to acknowledge the cooperation of the Scout Project Office at Langley Research Center in permitting acoustic measurements to be made on the Scout vehicle and the cooperation of the Scout Project Office at Ling-Temco-Vought in integrating the acoustic channel into the "E" section telemetry system. Many thanks are due for the assistance supplied by the LRC Mission Support Office, WTR. Without the understanding and help supplied by Captain T. Sandford and the men of the SLV-1 Launch Team of the 6595th Aerospace Test Wing, the launcher measurements could not have been made.

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland, December 7, 1970
697-06-01-24-51

Reference

1. Nagy, J. A., "Flight Performance Data from the Scout X-258 Rocket Motor", NASA Technical Note D-2756, May 1965.

*Inter-Range Instrumentation Group.

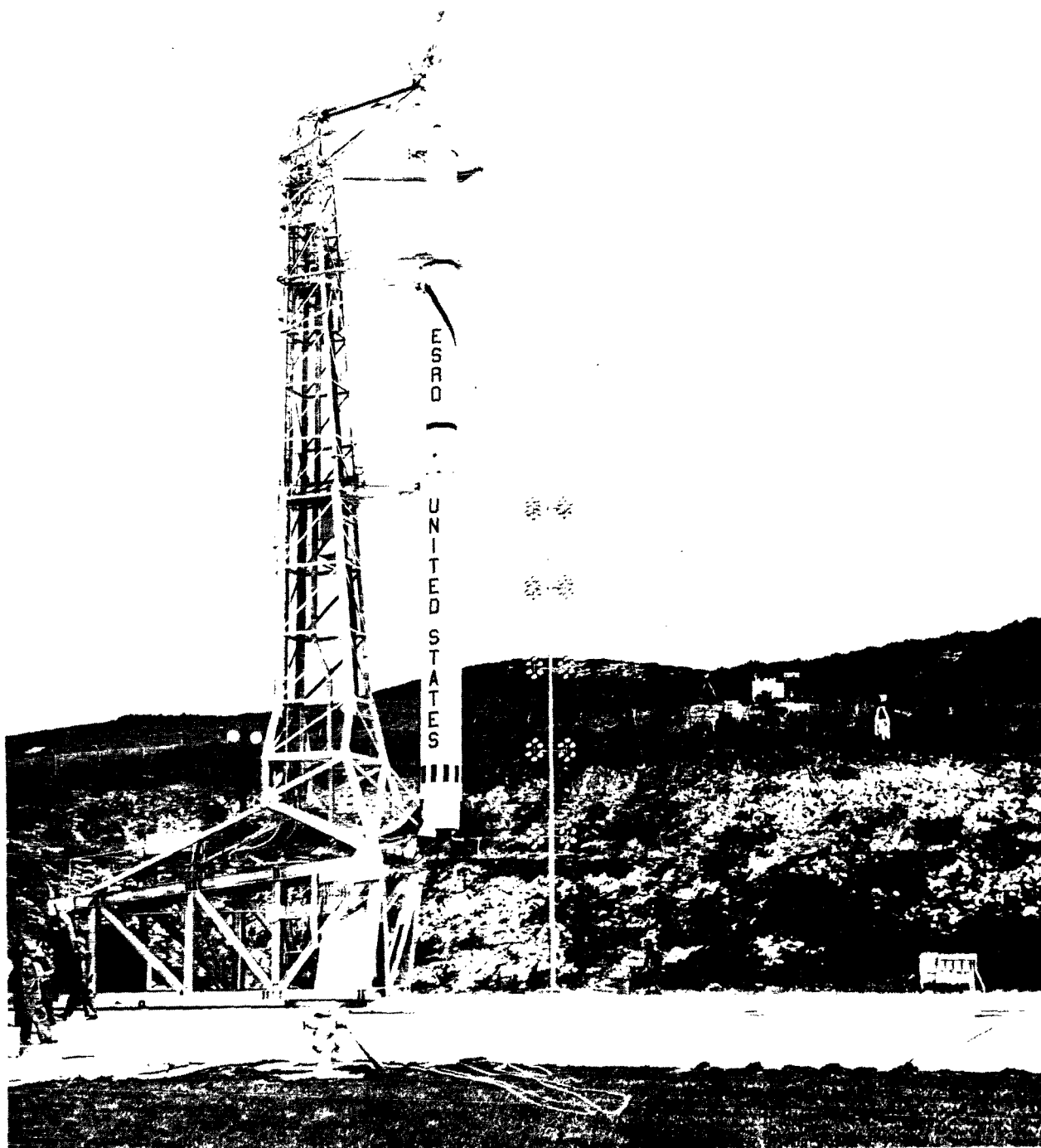


Figure 1—Scout S-172C on its launcher.

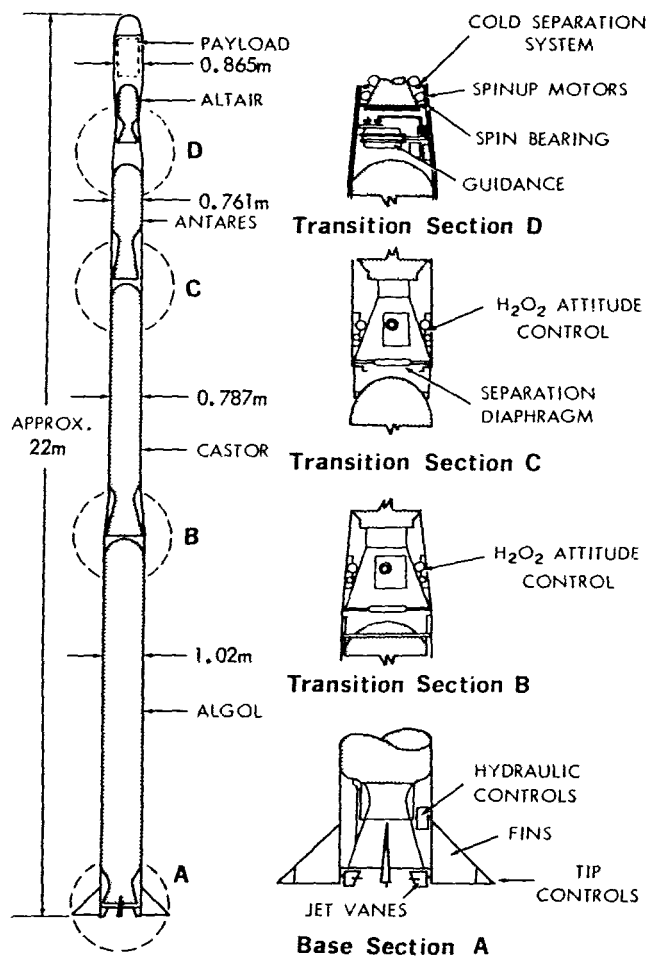


Figure 2—General arrangement of vehicle.



Figure 3—Air Force Western Test Range space launch complex 5.

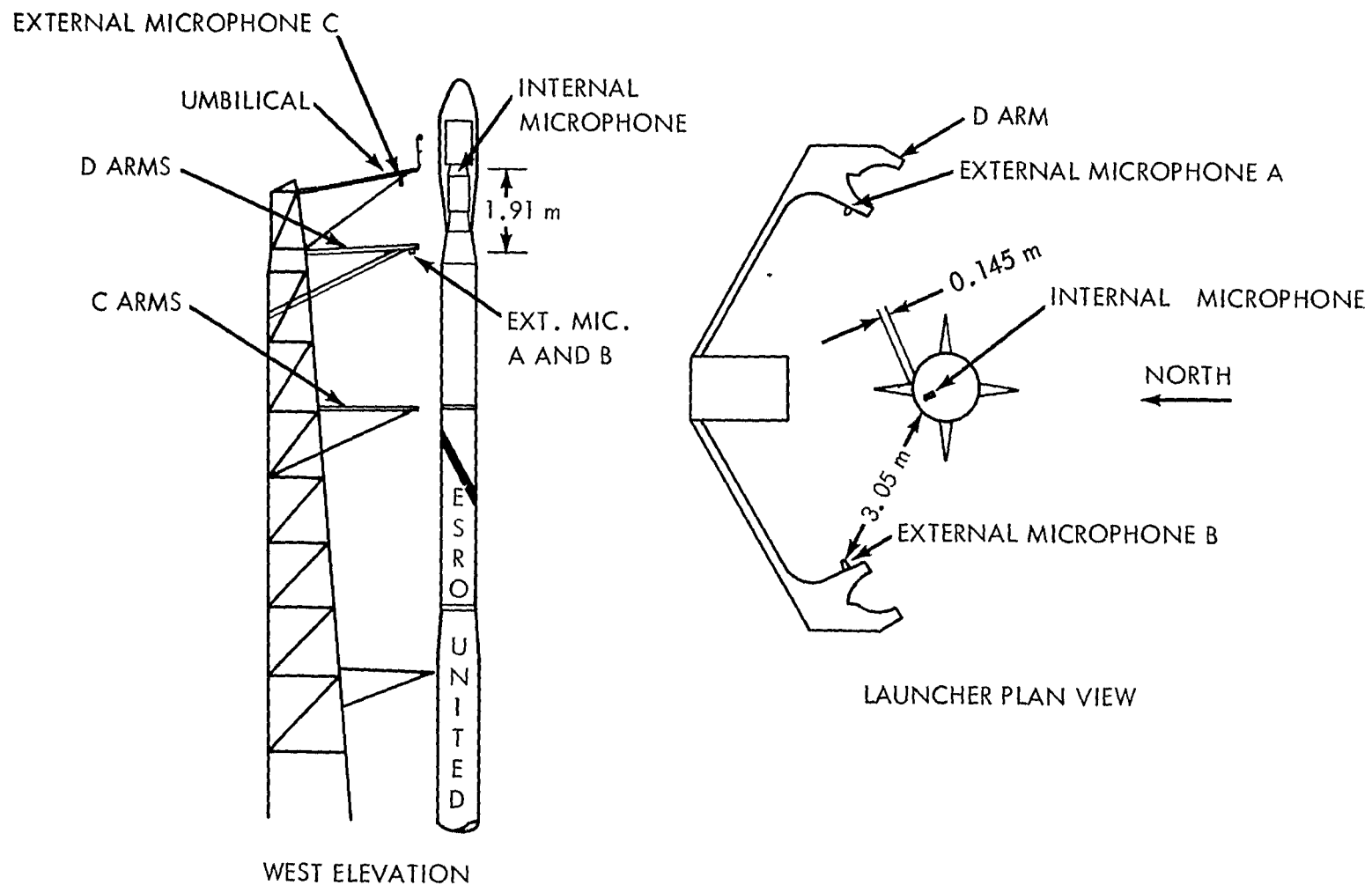


Figure 4—Launcher microphone location.

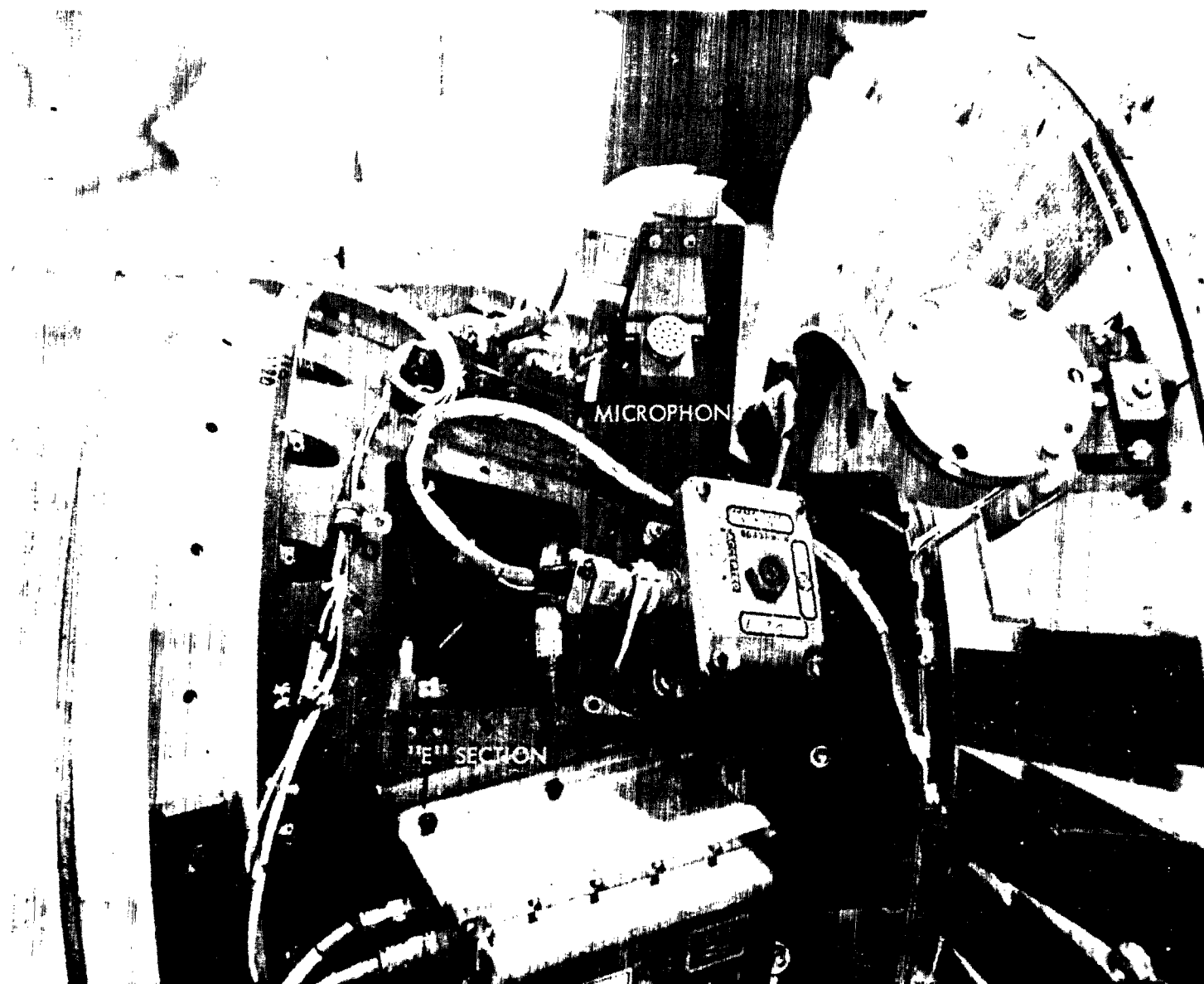


Figure 5—Internal microphone located on "E" section umbilical bracket.

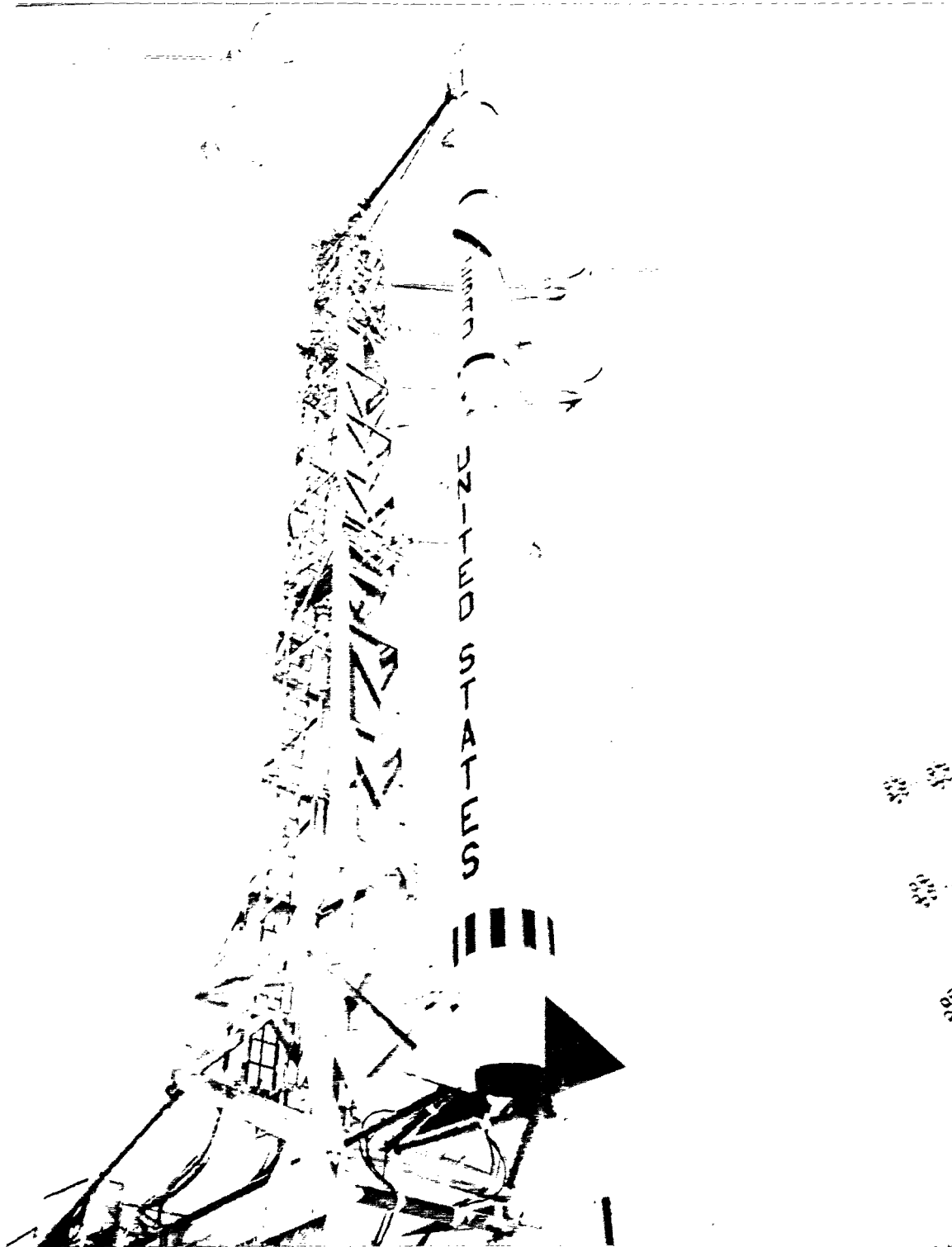


Figure 6—Scout S-172C showing open "D" arms.

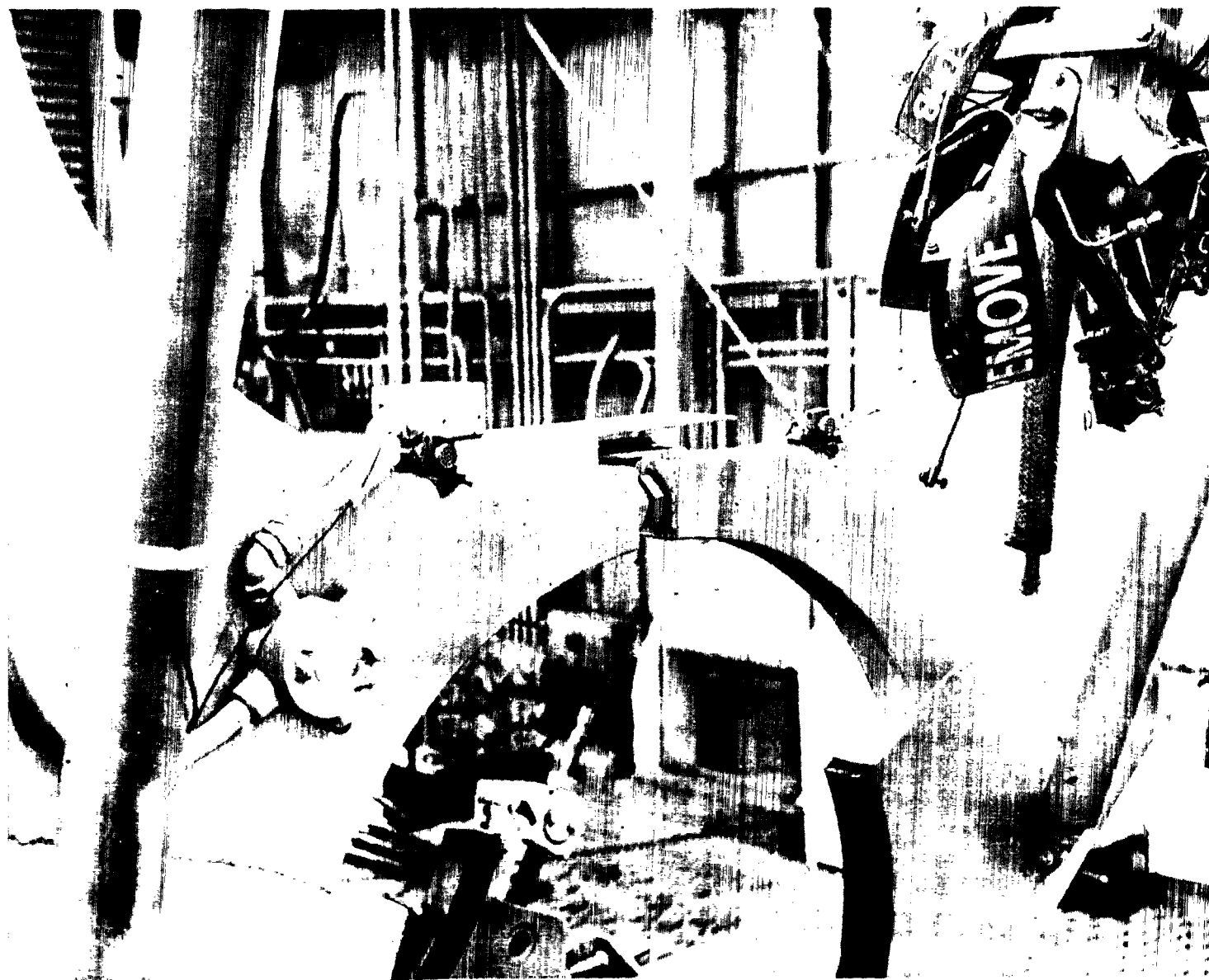


Figure 7—External microphones located on "D" launcher arms.

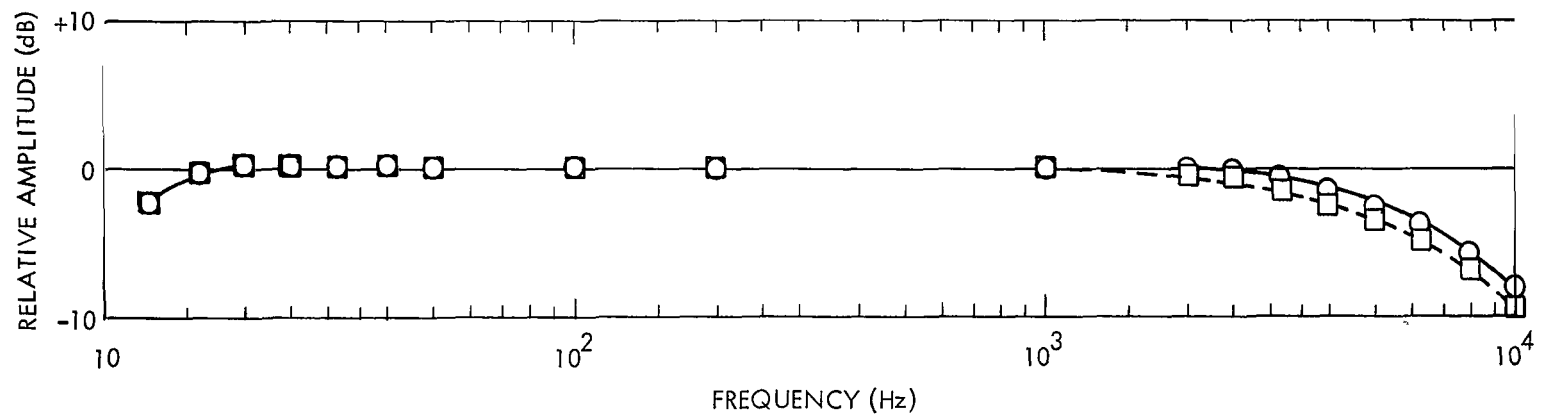


Figure 8a—Frequency response of the launcher microphone system and analysis equipment.

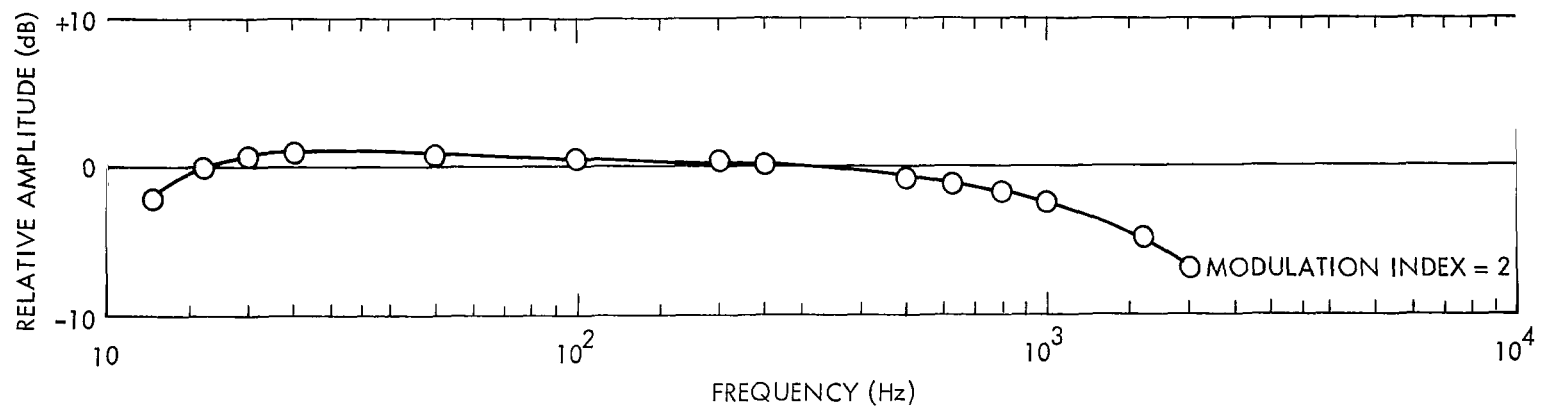


Figure 8b—Frequency response of the flight microphone system, flight tape recorder, and analysis equipment.

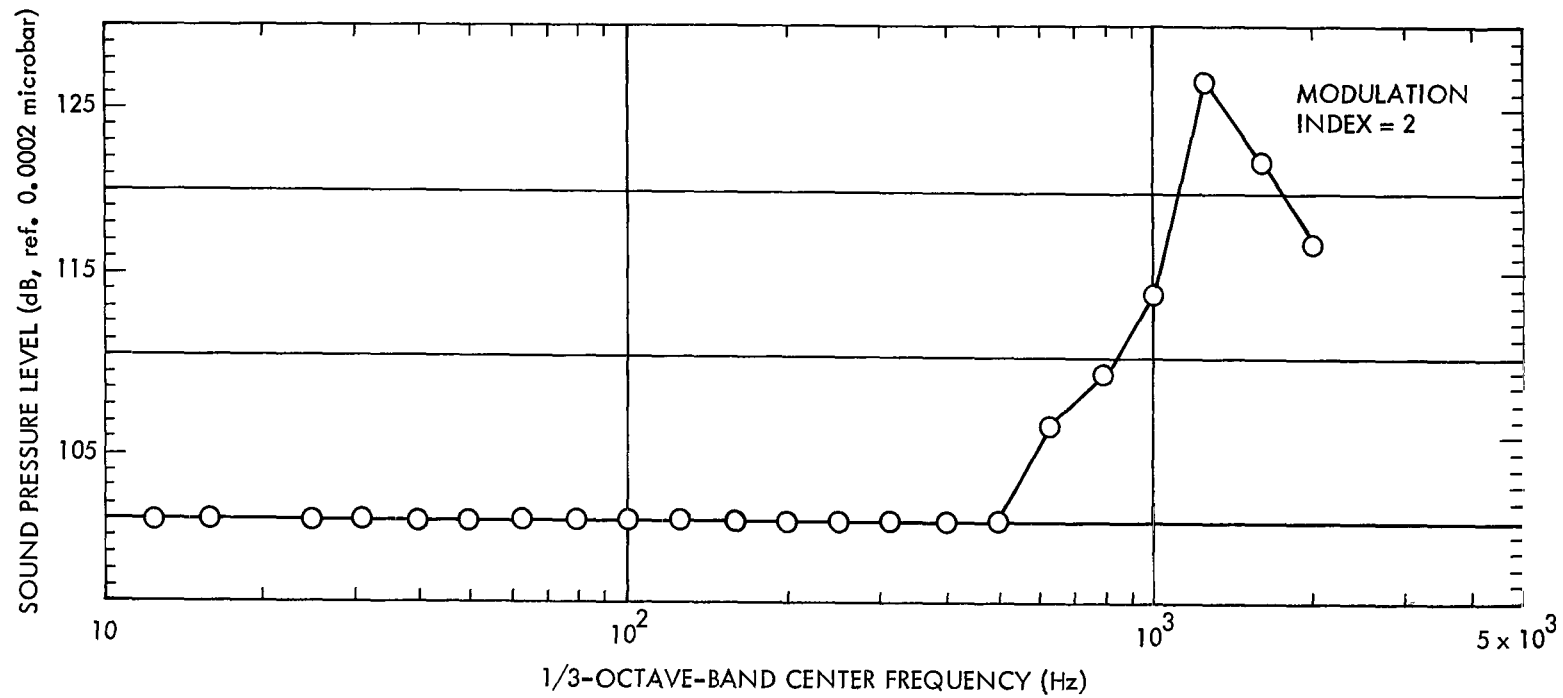


Figure 9—Scout 172C, 1/3-octave-band analysis of the flight data background noise.

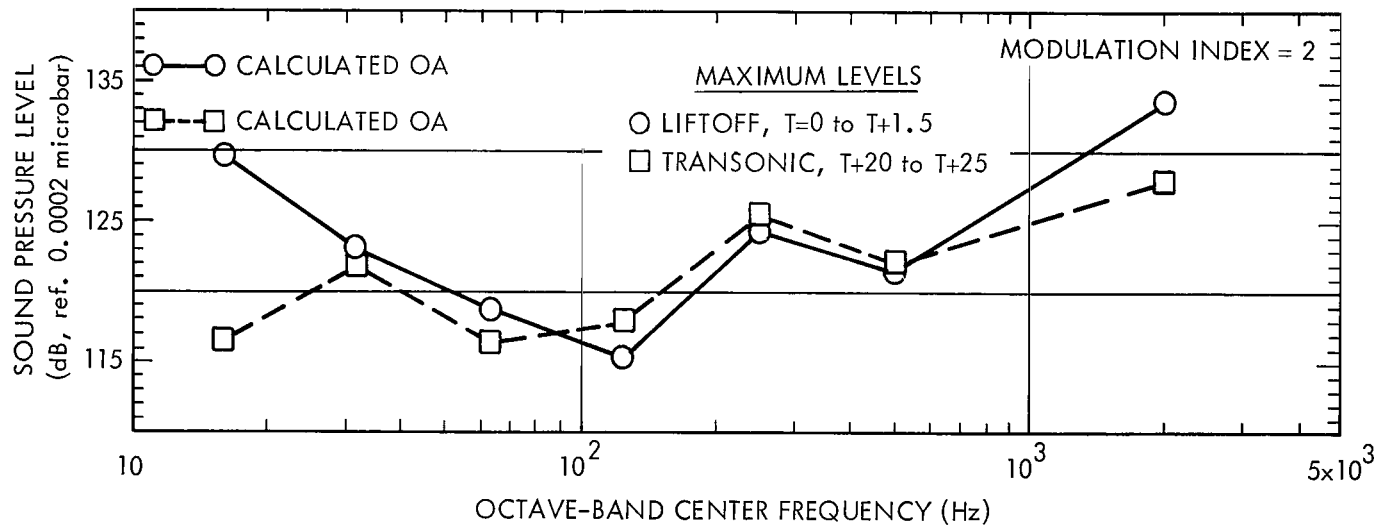


Figure 10a—Scout 172C in-flight octave-band acoustic noise levels.

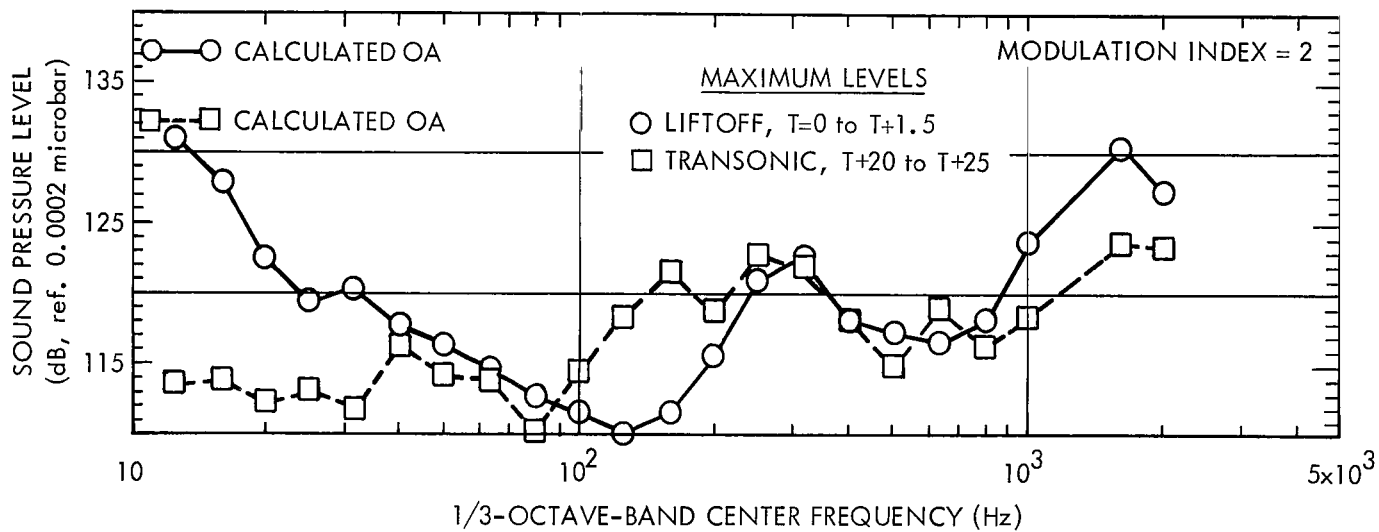


Figure 10b—Scout 172C in-flight 1/3-octave-band acoustic noise levels.

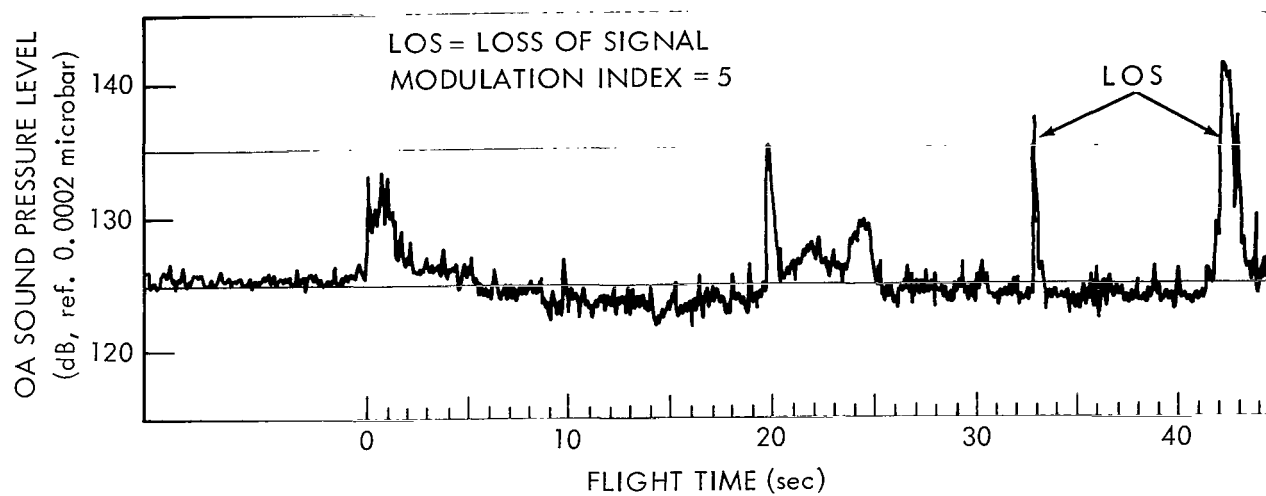


Figure 11a—Flight-microphone acoustic noise level (rms).

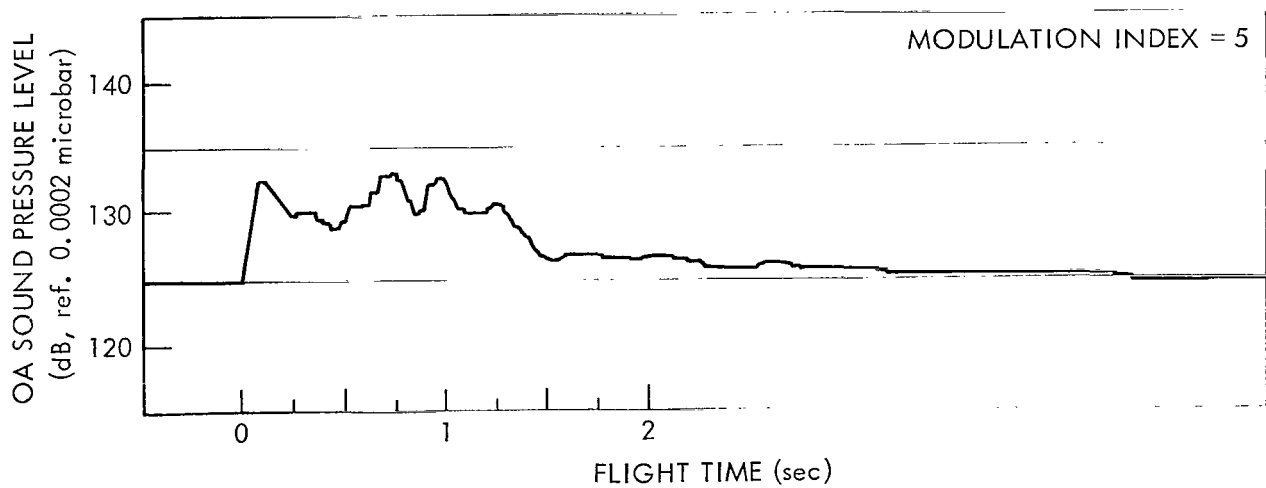


Figure 11b—Flight-microphone acoustic noise level (rms).

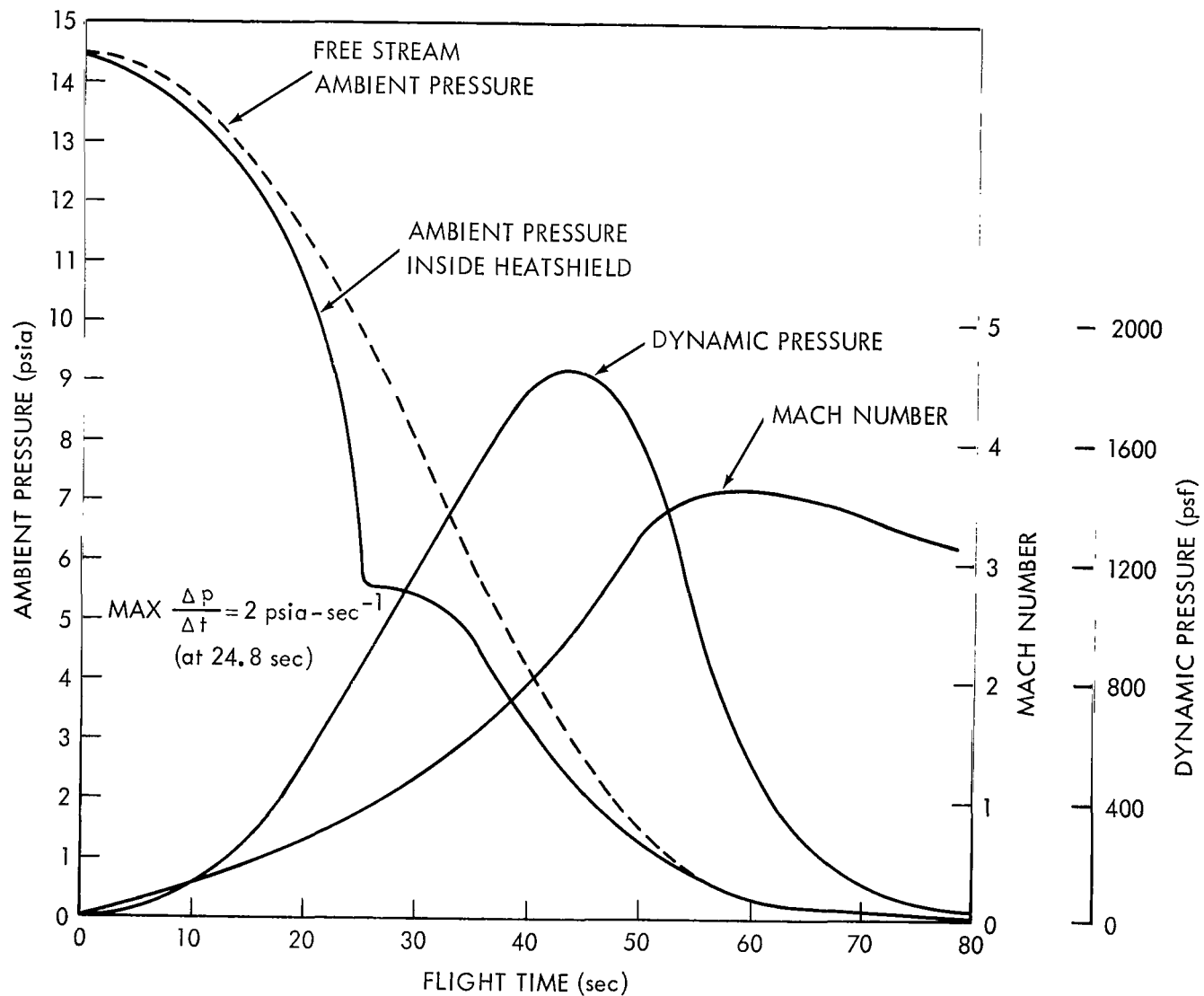


Figure 12*—Nominal flight parameters for S-172C.

*After Black and Latimer, *op. cit.*

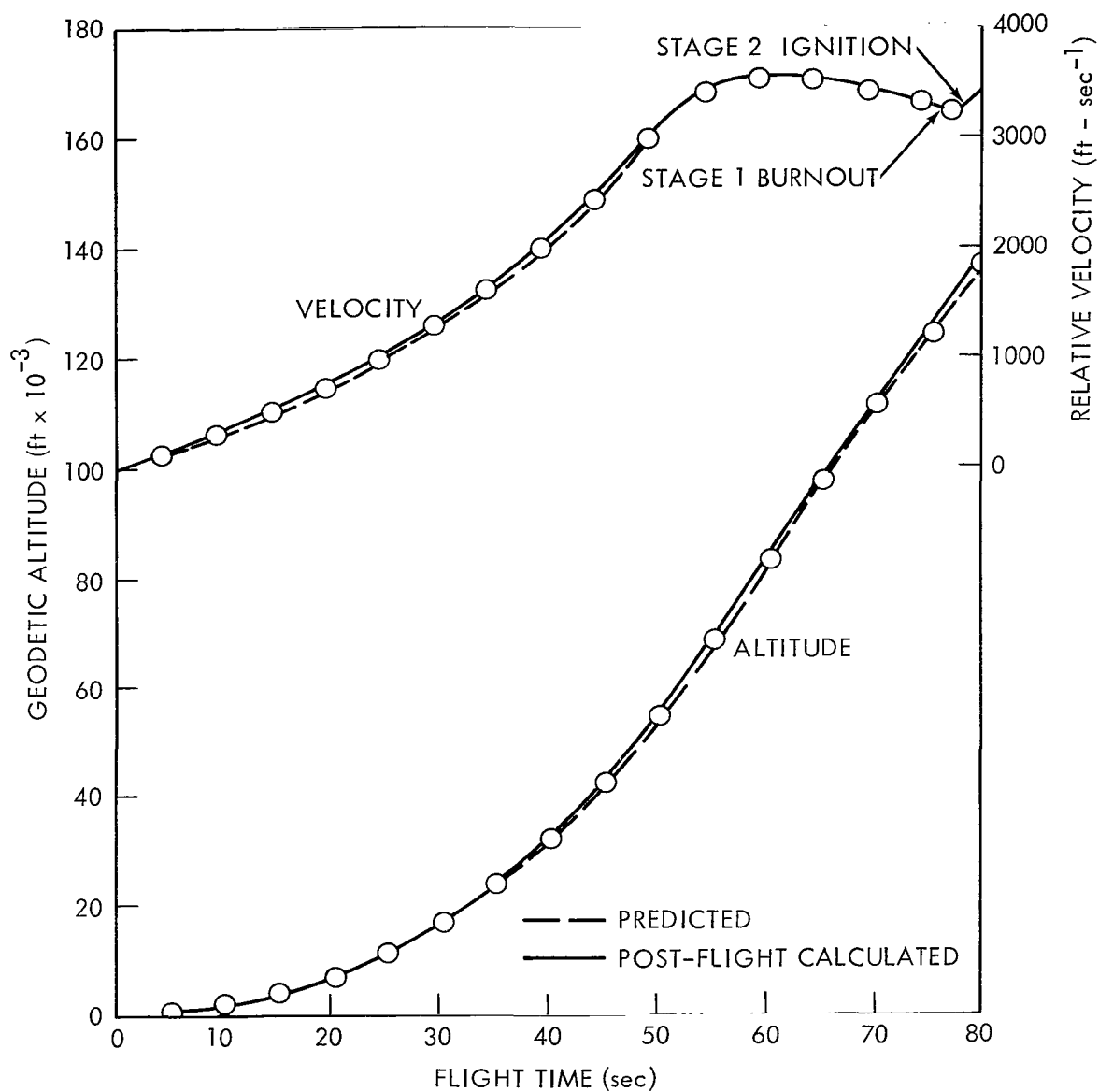


Figure 13*—Nominal flight parameters for S-172C.

*After Black and Latimer, *op. cit.*

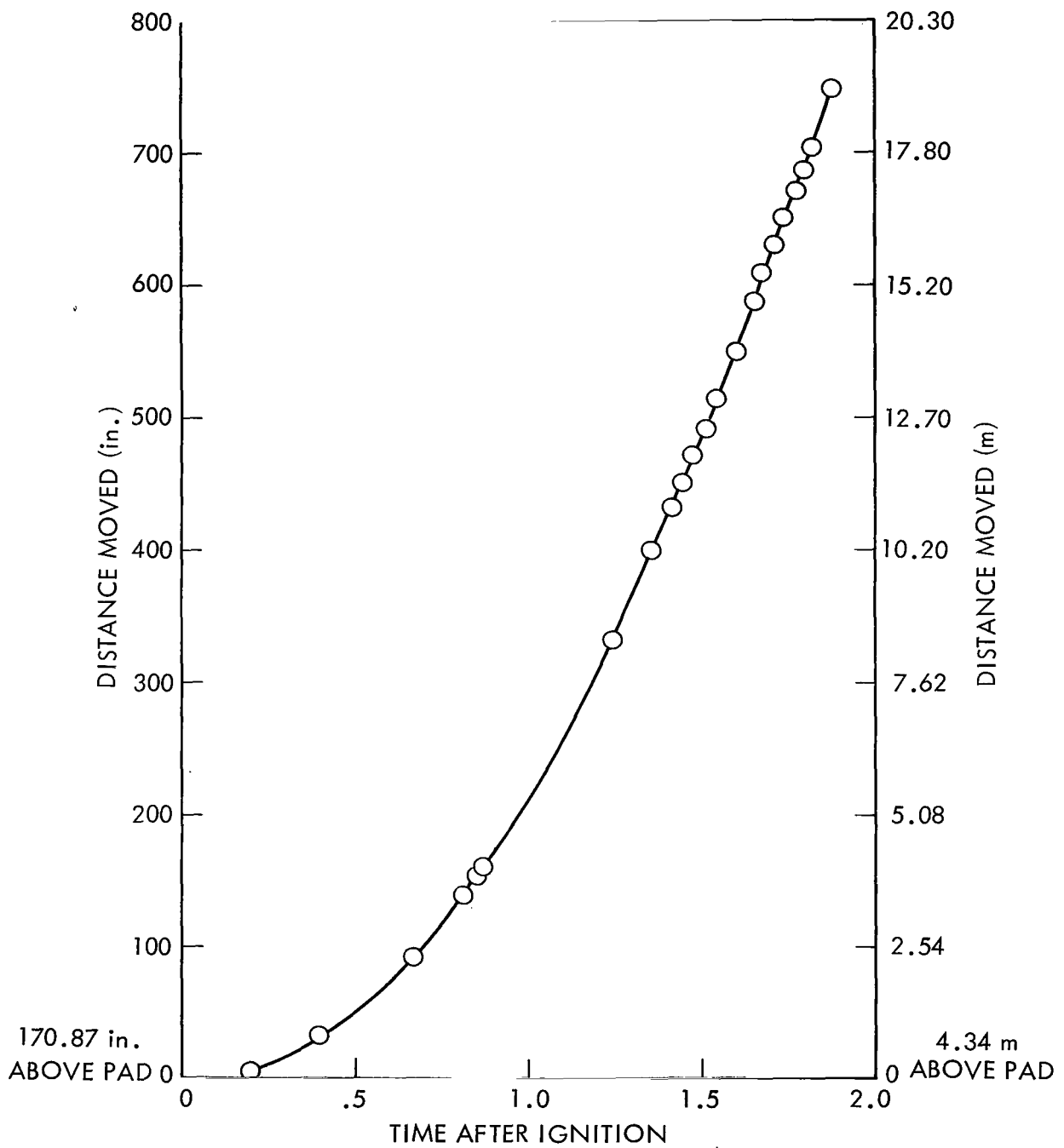


Figure 14—Detailed altitude plot for lift-off of S-172C.

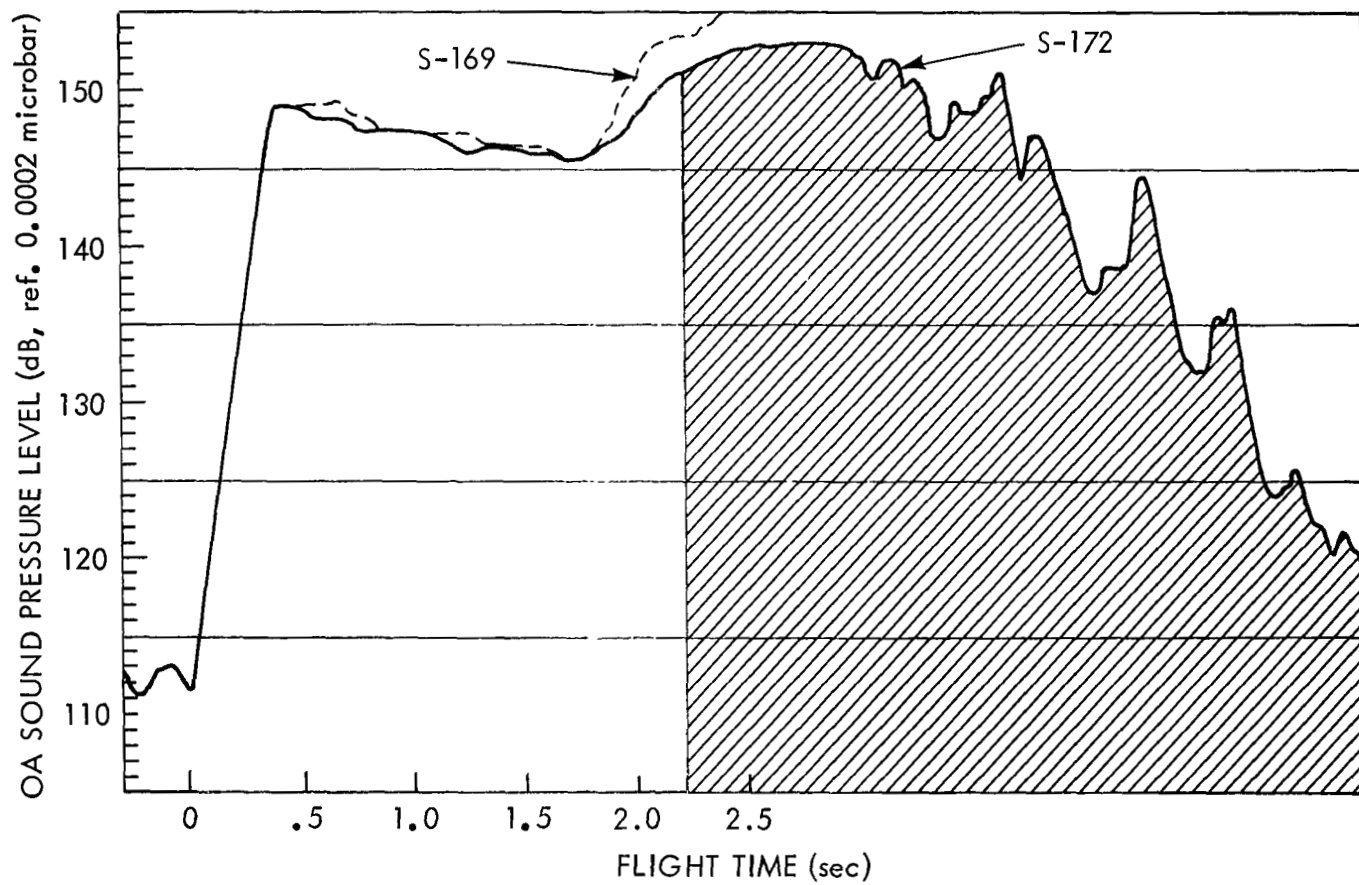


Figure 15—Launcher-microphone A: acoustic noise level (rms).

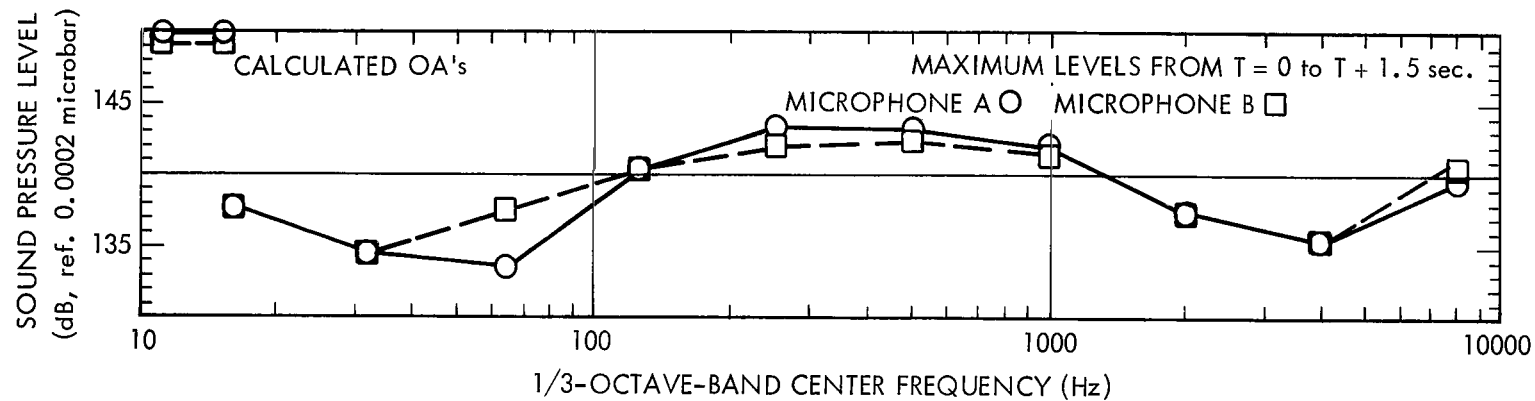


Figure 16a—Scout 172C launcher octave-band acoustic noise levels.

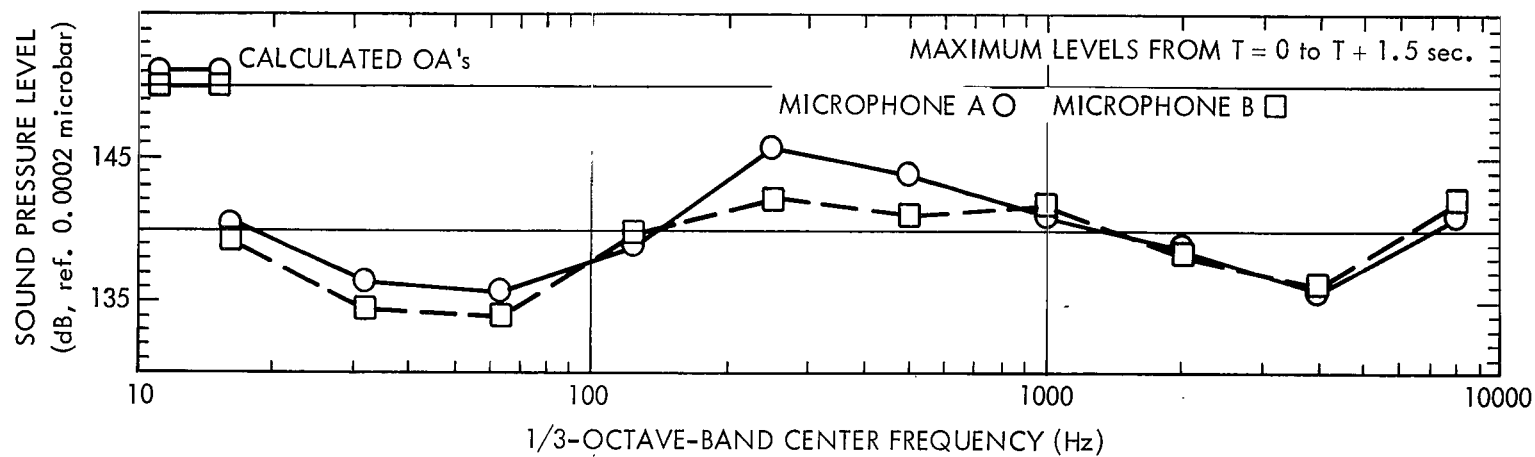


Figure 16b—Scout 169 launcher octave-band acoustic noise levels.

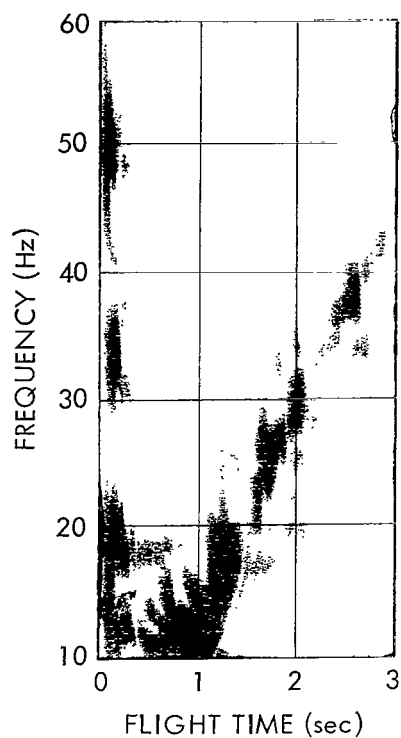


Figure 17a—Spectrogram of frequency vs time vs amplitude for the flight microphone.

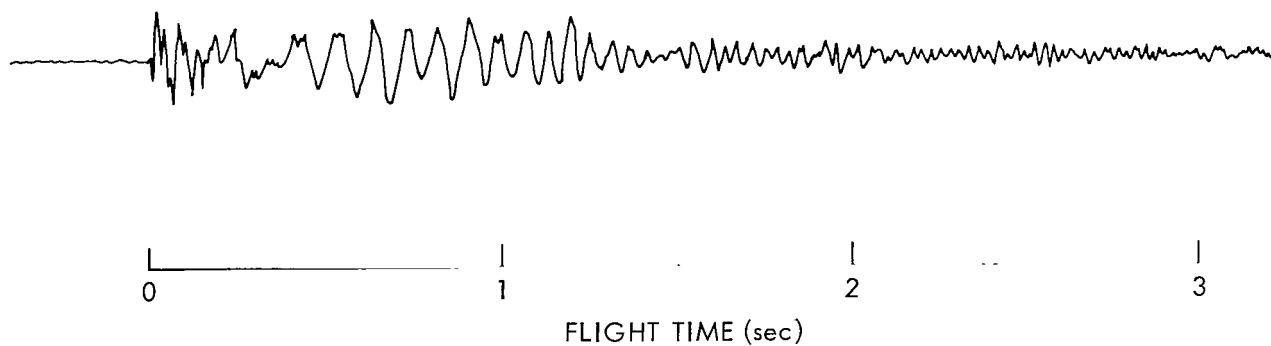


Figure 17b—Low-pass (50-Hz) filtered record of the flight microphone.

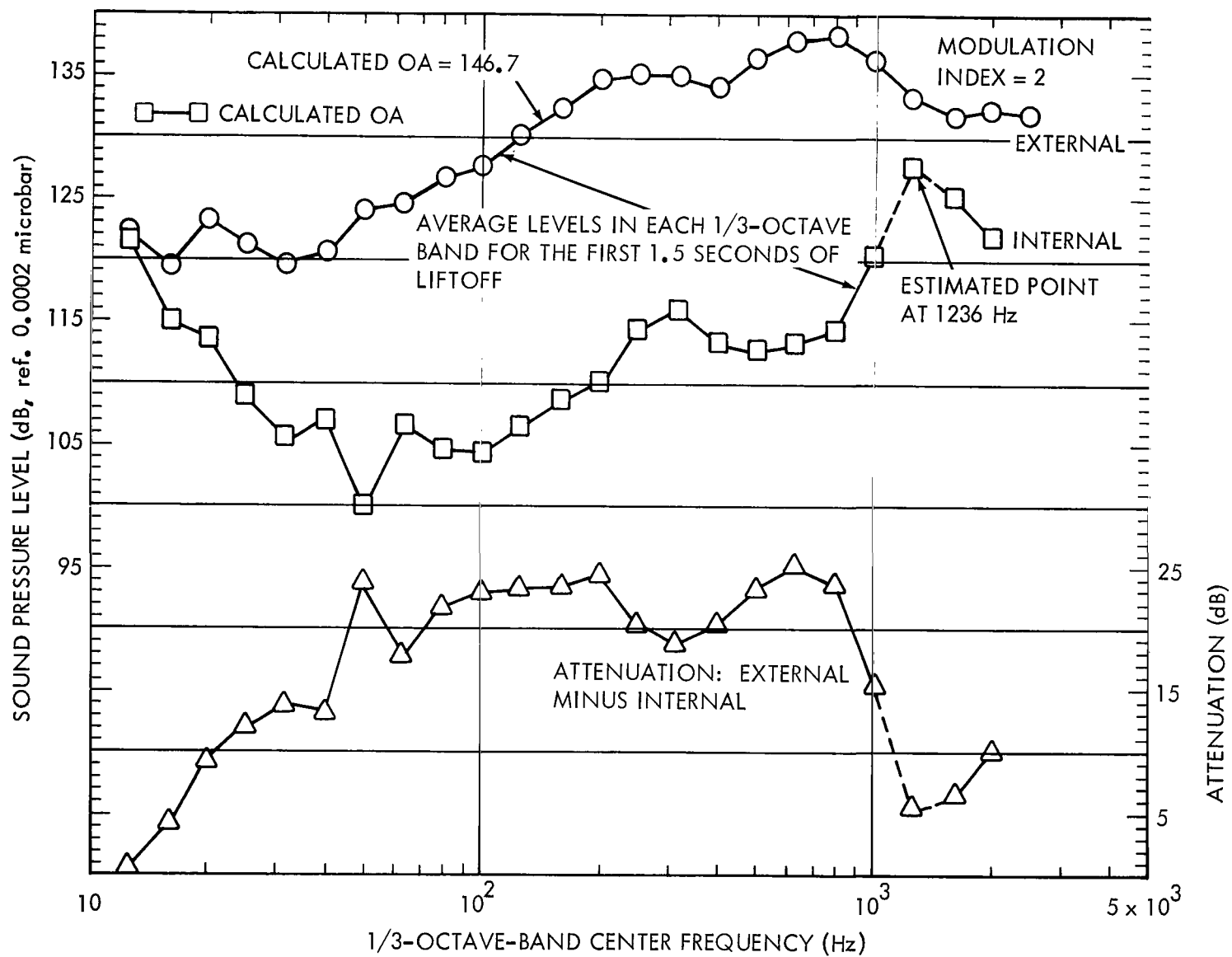


Figure 18—Scout 172C heat-shield noise attenuation characteristics.

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